SUCCESS CRITERIA AND RISK MANAGEMENT FOR THE NEW MILLENNIUM PROGRAM

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ABSTRACT

The National Aeronautics and Space Administration (NASA) New Millennium Program (NMP) is a technology development and validation program that will flight-validate advanced, new technologies with space flight applications. NMP's purpose is twofold. First, it will develop technologies that will enable future spacecraft to be smaller, more capable and reliable, and to be launched more frequently. Second, it will validate the technologies in flight to reduce the risks to future science missions in flying these technologies for the first time. To measure the program's success, NMP has devised a set of criteria that stresses the relevance of technologies selected for flight validation to NASA's 21st-century science mission needs. Also, NMP has instituted a 'risk management' policy, where, through a combination of adequate resources and early risk assessment and risk mitigation plans for the technologies, the overall risk of the NMP flights can be rendered acceptable.

1. INTRODUCTION

The New Millennium Program will focus on enabling NASA's bold vision for space exploration in the new millennium, a vision that consists of frequent, low-cost access and massive outreach to space that will further mankind's quest for existential knowledge. In order to develop advanced technologies for space flight, NMP has created Integrated Product Development Teams (IPDTs), made up of members from government, industry, and academia, for each of its technology-focus areas: i) Autonomy, ii) Microelectronics, iii) Communications, iv) Instrument Technologies & Architectures, v) In situ Instruments and Microelectromechanical Systems, and vi) Modular and Multifunctional Systems. These IPDTs will establish and maintain roadmaps for their technology area that will guide the development of specific technologies as well as the general capabilities they provide[1]. The process for the selection of the technologies that will be validated on NMP flights has been developed and documented elsewhere [2].

Compared to more traditional *science-driven* programs, NMP is *technology-driven* in the near-term so as to validate technologies that will enable a higher science return in the future. For NMP to achieve its goal, it has to have a fundamentally different approach to both risk management as well as its success criteria centered around technology validation for future customers. The NMP policies and criteria are stated herein, then expanded and rationalized as they apply within the context of a technology validation program.

?. PROGRAM SUCCESS CRITERIA

The success of a technology validation flight is measured both by the intrinsic value of the flight itself (that is, by the successful validation of its technologies and the science information returned), and by the benefit that the validated technologies provide to science missions of the 21st century. Program success is measured by the criteria listed below:

a. The relevance of the selected technologies and the IPDT roadmaps to future science mission needs.

b. Risk reduction to 21st-century science missions by having technology flight validated.

c. Design of the diagnostic system for validation of technology performance.

d. Science returned from the flight.

The relevance of the selected technologies and the IPDT roadmaps to future science mission needs: The NMP has two concurrent processes in place: 1) technology roadmapping by IPDTs: and 2) technology selection for flight validation. The technology roadmaps are designed to provide the direction for technology development and flight validation, which then provides the capabilities needed for the science missions of the 21st century. The success of the roadmapping effort is measured by how well it identifies the technologies that are eventually selected, validated, and then incorporated into future science missions. Moreover, since future science mission requirements change as our scientific knowledge expands, another measure of success of the roadmaps is how applicable they are to the evolving needs of the science missions of the 21st century.

The selection of a technology for flight validation is based on: a) its impact on 21st-century science missions; b) its revolutionary nature; and c) the risk reduction offered by its flight validation. At the time when technologies are selected for flight there exist two major uncertainties: i) how they will perform in flight compared to how they have been predicted to perform; and ii) how successfully, once validated, they will provide the capabilities and meet the ever-changing needs of science missions of the 21st century. While our knowledge regarding these two uncertainties will not be complete at the end of a validation flight, it will be significantly better than it was before the flight. Thus a flight's success will also be judged by our a priori assessment of these uncertainties, that is, whether or not we selected and validated the relevant high pay-off technologies.

The risk reduction by having flight validated a technology: In today's cost constrained environment most science missions have severe cost caps and thus are reluctant to accept the risks of flying new technologies. The NMP is designed to reduce the risk for future science missions that baseline the newly validated technologies. The extent to which any NMP flight does this for a future science mission is a measure of the flight's success.

The design of the diagnostic system to validate the technology performance: Flight validating an NMP technology is an experiment in itself and the diagnostic system flown with the technology must be designed with this in mind. In typical science missions, the diagnostic system is designed to ensure success in the event of an inflight failure by assisting ground control operations in the selection of redundant paths or mission work-around approaches. All these are actions designed to best salvage a crippled mission. In a technology-validation flight, the diagnostic system has to go a step further so that adequate diagnostic capability is designed and incorporated to help determine why failure of a technology occurs.

The science returned from the flight: While it is recognized that the NMP program is fundamentally a technology validation program, it is also designed to derive scientific information from each flight. Though the flight designs and profiles are driven by their intrinsic technology validation value, once these basic parameters are established, it is the task of the flight designers to obtain the maximum science data that can be returned from the flight within its programmatic cost and schedule constraints. The extent to which useful science information is returned from the flight is a measure of success of the flight.

3 PROGRAM RISK MANAGEMENT

The NMP risk management policy is based on the following five guidelines, discussed in detail:

a. NMP shall not require flight-proven technologies as backup for new technologies.
b. Single-string design with selected redundancy is acceptable.
c. Cost-effective risk-avoidance practices shall be employed.
d. Technologies shall be categorized according to their role in a mission.
e. Flight incorporation of selected technologies into flight projects is contingent upon the successful completion of three technology *gates* (peer-reviews).

NMP shall not require flight-proven technology as backup for new technology: When first implementing a new technology for a mission, there is a tendency on the part of mission designers to want to back it up with a proven state-of-the-art technology, particularly when the new technology is being used for a mission-critical application. However, this kind of traditional approach, while minimizing overall mission risk, does have some shortfalls. In a cost- and weight-constrained environment, the addition of state-of-the-art backup technology places a high demand on the mission's cost and weight resources, and thus reduces the number of new technologies that can be validated on any given flight.

It should also be noted that the risks associated with new technologies refer more to those inherent in the process of developing the technologies for flight readiness within cost and schedule, than to the possibility of their failure during flight. In other words, the problems of failure of new technologies during flight validation are not as frequent as the cost and schedule problems that arise when developing new technologies. *This NMP policy is intended to focus attention on the phase where the problems usually occur, that is, on the technology development phase.*

Single-string design with selected redundancy is acceptable: The NMP validation flights are designed to have lifetimes of two years or less, which is well within the capability of flights with single-string designs. In fact, most of today's planetary missions to Mars and Venus use single-string designs. However, this policy does allow for the use of redundancy within any given subsystem, whether it be standard technology or new technology that is used for this purpose, which again is consistent with today's design practices.

Cost effective risk-avoidance practices shall be employed: When formulating risk-avoidance decisions two parameters must be brought into play: 1) The cost impact if a risk occurs during flight and 2) the probability of that risk occurring. The cost impact of recovering from a risk if it occurs is termed the "risk value", which is actually a negative cost in the strict accounting sense. If this "risk value" is multiplied by the probability of the risk occurring, the product gives us the "expected value" of the risk. It is this "expected value" figure that should be used when formulating decisions regarding risk, not the "risk value" figure itself. In cases when statistical data is not available to generate a figure for the probability of a risk occurring, good, common sense engineering judgment must be used. In any case, one must always be assessing the *probability* of a risk occurring, along with the cost of recovering from the risk, when deciding what course of action to take, especially in a cost-conscious environment.

The technologies shall be categorized according to their role in the mission: The impact of failure of a technology to achieve readiness on schedule depends on the nature of the technology and its assigned role in the flight. To assess this impact and designate the manner in which the development process must be managed, the Flight Project Manager will classify the technologies into the following three categories: Essential, Fundamental, and Enhancing.

Category I Essential: Technologies in this category are essential to the mission; the proposed flight cannot be carried out as designed without this technology. An example is solar electric propulsion (SEP) for the first deep space flight. Without SEP, flyby of the selected comet and asteroids cannot be achieved on the designated launch vehicle. Thus, failure to achieve readiness in time for flight would require a redesign of the mission itself. In general, only a few technologies will be selected in this category.

Category II Fundamental: These technologies are fundamental in that the mission cannot be carried out as defined without this functional capability, but existing technologies could be substituted if the breakthrough technology does not pass all three gates. Since the aim of the NMP flights is to provide testbeds to demonstrate new capabilities in their full operational mode, the majority of technologies selected are expected to fall into this category.

Category III Enhancing: Technologies in this category enhance the overall technology value of the mission, and are considered experiments. The functional capabilities they provide are not required for the completion of the mission as designed, and therefore if they do not pass the three gates, the mission can simply be flown without them. Typically, these technologies represent key enabling features of future capabilities flown as precursors of the full system capability.

Flight incorporation of technologies shall be determined by successfully passing three gates: Program management has defined three readiness *gates*, through which the technologies must pass on their way to flight acceptance: 1) Technology Readiness Review, 2) Key Technology Hardware/Software Demonstration, and 3) System Hardware/Software Demonstration.

Technology Readiness Review. The first gate consists of a written review of the respective technology's readiness state by a peer review group (selected by the Flight Project Managers), who are experts in the field of that particular technology. The review will cover the status of the technology's development to date, and the cost needed to deliver it on schedule for infusion into the validation flight. The review will also cover the proposed in flight validation approach. The Technology Readiness Review will be conducted before or during the first project-level review of the flight. If the technology successfully passes this gate, indicating a viable plan to develop and deliver the technology within budget and on time, it will move on to the next gate.

Key Technology Hardware/Software Demonstration. The second gate will consist of a demonstration of the key features of the technology's hardware and/or software, to determine whether they meet planned specifications, and whether the development is on schedule. This demonstration will be conducted before or during first review of the detailed design of the flight. A review group consisting of experts in the relevant technology and flight system experts will be designated by the Flight Project Manager.

System Hardware/Software Demonstration. The third and final gate consists of a system-level demonstration of the technology's hardware and software. At this gate, the technology will be tested yet again, to determine whether the overall system functions as specified and whether the technology will meet its delivery deadline. Maintaining as much continuity as possible, the Flight Project Manager will identify a review group to carry out this final review. The third gate will be conducted before the state of assembly, test, and launch operations.

4. CONCLUSIONS

The New Millennium Program will develop and validate it>\'olLItioll:ily" technologies and capabilities to infuse into NASA's ambitious science missions of the next century. Since the Nh41' is a Iccl]]lol(~{\y-(iii\'c]] program whose customers are future NA SA space and Earth science missions, it has developed a set of assessment criteria for the program's success that focus on this relationship. NM]' is also taking a higher-risk approach with its flights, in terms of the technologies being flown, than is possible for a science program. But with a strong risk management approach during the technologies' developm ent phase, when problems usually occur, NMP expects to minimize the vulnerability **of** its flights to the incorporation of these advanced, high-risk technologies.

5. REFERENCES

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2. B.A. Wilson, *New Millennium Technology Selection Process Plan*, JPL D-13361 (1996)

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